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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA-13412 (SEPTEMBER 1999)
NASA
SUPERSEDING NASA-13412 (MARCH 1999)

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SECTION 13412

INSTRUMENTATION
09/99

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NOTE: Delete, revise, or add to the text in this section to cover project requirements. Notes are for designer information and will not appear in the final project specification.

This section covers several typical types of instrumentation and control cables. Delete or add cables as required by the project requirements. The drawings should indicate the types, routing, and installation details of the cables.

Designer must provide under this section a complete list of cable types, including application specifications; when applicable, a complete list of cable and harness assembly fabrication drawings and procedures; and complete lists of connector specifications and types for the job.

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PART 1 GENERAL

1.1 REFERENCES

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NOTE: The following references should not be manually edited except to add new references. References not used in the text will automatically be deleted from this section of the project specification.

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The publications listed below form a part of this section to the extent referenced:

ASTM INTERNATIONAL (ASTM)

ASTM B 258 (1981; R 1991) Standard Specifications for Standard Nominal Diameters and Cross-Sectional Areas of AWG Sizes of Solid Round Wires Used as Electrical

	Conductors
ASTM B 3	(2001) Standard Specification for Soft or Annealed Copper Wire
ASTM B 33	(1994) Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes
ASTM B 5	(1989) Standard Specification for Electrolytic Tough-Pitch Copper Refinery Shapes
ASTM B 8	(1999) Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft
ASTM D 1248	(1984; R 1989) Standard Specification for Polyethylene Plastics Molding and Extrusion Materials
ASTM D 4066	(1994; Rev B) Standard Specification for Nylon Injection and Extrusion Materials (PA)

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE Std 45	(1983; R 1988) Recommended Practice for Electric Installations on Shipboard

U.S. AIR FORCE TECHNICAL ORDERS (TO)

TO 31-10-27	(1994; CHG 3 1983) Standard Institutional Practices, Equipment Designations
TO 31W3-10-15	(1980; CHG 3 1982) Outside Plant Cable Testing

U.S. DEPARTMENT OF DEFENSE (DOD)

MS MIL-C-13777/GEN	(Rev G; Am 1, Supple 1) Cable, Special Purpose, Electrical, Conductors
MS MIL-C-17/28	(Rev C) Cables, Radio Frequency, Flexible, Coaxial, 50 Ohms, M17/028-RG058
MS MIL-C-17/75	(Rev F) Cables, Radio Frequency, Flexible, Coaxial, 50 Ohms, M17/75-RG214 and M17/75-RG365
MS MIL-C-17/GEN	(Rev G; Supple 1) Cables, Radio Frequency, Flexible and Semirigid
MS MIL-C-22931/11	(Rev A) Cables, Radio Frequency,

	Semirigid, Coaxial, Semi-Air-Dielectric, 0.875 to 1.005 Inches Outside Diameter, 50 Ohms
MS MIL-C-22931/13	(Rev A) Cables, Radio Frequency, Semirigid, Coaxial, Semi-Air-Dielectric, 1.625 to 1.830 Inches Outside Diameter, 50 Ohms
MS MIL-C-9660	(Rev A; Am 3) Cables, Composite Telephone and Television (16 AWG, Video Pair Polythylene Insulated and 19 AWG, Paper Insulated, Lead Covered, and Tape Armored)
MS MIL-E-15090	(Rev C; Am 2) Enamel, Equipment, Light-Gray (Formula No. 111)
MS MIL-F-3922/GEN	(Rev B; Am 3, Supple 1F) Flanges Waveguide, General Purpose
MS MIL-I-631	(Rev D; Am 6) Insulation, Electrical, Synthetic-Resin Composition, Nonrigid
MS MIL-W-16878/GEN	(Rev E; Am 1, Supple 1A) Wire, Electrical, Insulated
MS MIL-W-85/GEN	(Rev G; Int Am 1) Waveguide, Rigid, Rectangular

1.2 GENERAL REQUIREMENTS

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NOTE: If Section 16003, "General Electrical Provisions," is not included in the project specification, applicable requirements therefrom should be inserted and the following paragraph deleted.

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Section 16003, "General Electrical Provisions," applies to work specified in this section.

1.3 SUBMITTALS

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NOTE: Review submittal description (SD) definitions in Section 01330, "Submittal Procedures," and edit the following list to reflect only the submittals required for the project. Submittals should be kept to the minimum required for adequate quality control. Include a columnar list of appropriate products and tests beneath each submittal description.

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The following shall be submitted in accordance with Section 01330, "Submittal Procedures," in sufficient detail to show full compliance with the specification:

SD-01 Preconstruction Submittals

The following shall be submitted in accordance with paragraph entitled, "Manufacturer's Information," of this section.

Manufacturer's Instructions
Material, Equipment, and Fixture Lists

SD-03 Product Data

Manufacturer's catalog data shall be submitted for the following items. Data shall include a complete list of parts, special tools, supplies with current unit prices, and source of supply.

Communication Cable
Coaxial Cables
Waveguides

SD-06 Test Reports

Test reports shall be submitted for the following tests in accordance with the paragraph entitled, "Field Testing," of this section. A test plan that includes detailed step-by-step procedures for the cable field test required by this specification and the calibration details for test instruments shall be submitted for approval a minimum of 30 days prior to any cable testing.

Acceptance Testing
Pressure Test
Leakage Test

SD-07 Certificates

Certificates shall be submitted for the following items showing conformance with the referenced standards contained in this section.

Communication Cable
Coaxial Cables
Waveguides

1.4 PERSONNEL QUALIFICATIONS

Cable construction work shall be performed by construction personnel who have had at least 3 years' experience in placing cables in conduit, cable trays, and underground duct systems.

Communication Cable splices and terminations shall be made by journeymen

cable splicers who have had a minimum of 5 years' experience in splicing and terminating communication cables.

Instrumentation cable terminations and connector installation shall be performed by journeymen who have had at least 3 years' experience in this type of work.

Journeymen with less than the required experience may be qualified by extensive testing in the performance of work of all types of terminations or splices in the presence of the Contracting Officer or his designated representative. Each individual who is to perform cable splicing may be required to perform a minimum of one acceptable sample splice of each type of cable to be spliced. Each individual who is to perform instrumentation and communication cable termination work may be required to fan, form, and terminate one acceptable cable sample; demonstrate fundamental knowledge of inside cabling in conduit, ducts, trays, and cable racks; and demonstrate fundamental knowledge of support and arrangement of inside cables to racks and cabinets. Sample splices, fanning, forming, and terminations shall not be incorporated on the job.

1.5 MANUFACTURER'S INFORMATION

Manufacturer's Instructions shall be submitted indicating the type of tools to be used and the procedures to be followed for installation, including the calibration of tools.

Material, Equipment, and Fixture Lists shall be submitted for Communication Cable systems including manufacturer's style or catalog numbers, specification and drawing reference numbers, warranty information, and fabrication site information.

PART 2 PRODUCTS

2.1 CABLE TYPES

2.1.1 2(2NO.12)MI

Cable type 2(2NO.12)MI shall be comprised of two solid single, untwisted AWG No. 12 -2.0 millimeter diameter (AWG No. 12) conductors, magnesium-oxide insulated, copper-sheathed, PVC-jacketed and shall have an operating voltage of 600 V-(ac) root mean square (rms). This cable type shall be used for instrumentation cable applications routed in conduit above and below grade, cable ducts, and cable trays.

Cable type 2(2NO.12)MI shall conform to the following design requirements:

Cable shall conform to the requirements of IEEE Std 45.

AWG No. 12 -2.0 millimeter diameter (AWG No. 12) copper conductors shall be in accordance with ASTM B 5.

Insulation shall be powdered, highly compressed magnesium-oxide.

Overall shield shall be copper tubing and shall conform to ASTM B 5.

Overall jacket shall be polyvinylchloride (PVC) jacket and shall be at least 0.625-inch 15.9 millimeter thick.

Factory tests: Cable shall be electrically tested prior to shipment with an inspection test voltage of 2500 volts and shall be mechanically tested using the impact, bend and twist tests.

2.1.2 46(22PTNO.22, 1PTSINO.14)OS

Cable type 46(22PTNO.22, 1PTSINO.14)OS shall have 46 total, conductors consisting of 22 twisted pairs of AWG No. 22 0.63 millimeter diameter (AWG No. 22) and one twisted pair of AWG No. 14 1.6 millimeter diameter (AWG No. 14). AWG No. 14 1.6 millimeter diameter (AWG No. 14) pair shall have an overall shield and jacket and shall be concentrically located within the cable. AWG No. 22 0.63 millimeter diameter (AWG No. 22) pairs shall be grouped around the AWG No. 14 1.6 millimeter diameter (AWG No. 14) pair with a lay pattern that will minimize crosstalk at audio frequencies. Cable shall have an overall shield and sheath of extruded polychloroprene. This type of cable shall have an operating voltage of 300 V-(ac) and shall be used for operational intercommunications systems and instrument cabling.

Cabling shall conform to MS MIL-C-13777/GEN.

Conductor installed shall consist of the following: Inner layer shall consist of one pair of AWG No. 14 1.6 millimeter diameter (AWG No. 14); first layer shall consist of 9 pairs of AWG No. 22 0.63 millimeter diameter (AWG No. 22); second layer shall consist of 13 pairs of AWG No. 22 0.63 millimeter diameter (AWG No. 22). Pair lengths shall be varied to minimize signal coupling.

Conductor AWG No. 22 .063 millimeter diameter (AWG No. 22) and AWG No. 14 1.6 millimeter diameter (AWG No. 14) shall conform to the following requirements:

Conductor material shall be annealed tinned copper conforming to ASTM B 33.

Insulation shall be polyethylene conforming to ASTM D 1248, Type II dielectric, Grade 5.

Conductor jacket material shall be extruded clear polyamide conforming to ASTM D 4066.

Extruded polyamide jacket shall be 0.003-inch 0.075 millimeter minimum thick.

Conductor twinning shall consist of 2 twisted insulated and jacketed conductors.

Conductor color coding shall be 1 white, 1 black conductor.

Maximum cable lay shall be 6.0 inches 150 millimeter.

Inner conductor AWG No. 14 1.6 millimeter diameter (AWG No. 14) shall conform to the following requirements:

AWG No. 14 1.6 millimeter diameter (AWG No. 14) conductors shall conform to MS MIL-W-16878/GEN and ASTM B 8.

Inner conductor stranding shall be concentric, Class C, 41/ 0.0103 inch 0.262 millimeter outside diameter (od), 0.078-inch 2.0 millimeter tinned copper.

Inner conductor's insulation thickness shall be .012-inch .31 millimeter minimum.

Inner conductor shield shall be braided AWG No. 36 0.125 millimeter diameter (AWG No. 36) tinned copper strands, with 85 percent coverage.

Overshield jacket material shall be extruded polyethylene conforming to ASTM D 1248, Type II dielectric, Grade 5.

Jacket material shall be 0.015-inch 0.38 millimeter minimum wall thickness.

First and second layer, AWG No. 22 0.63 millimeter diameter (AWG No. 22) conductors shall conform to the following requirements:

AWG No. 22 0.63 millimeter diameter (AWG No. 22) conductors shall conform to MS MIL-W-16878/GEN and ASTM B 8.

Conductor stranding shall be concentric, Class C, 19/ 0.0063 inch 0.16 millimeter od, 0.030-inch 0.75 millimeter tinned copper.

Insulation thickness shall be 0.010-inch 0.25 millimeter minimum.

Cable type 46(22PTNO.22, 1PTSINO.14)OS shall conform to the following requirements:

Cable fillers shall be polyethylene conforming to ASTM D 1248, Type II dielectric, Grade 5, as required to provide a round, firm cross section.

Cable barrier tape shall conform to MS MIL-C-13777/GEN and shall be made of 1 mil 0.025 millimeter minimum thick mylar (polyethylene terephthalate) with 10 percent minimum lap.

Overall shield shall be AWG No. 34 0.16 millimeter diameter (AWG No. 34) tinned-copper strands, braided, with 85 percent coverage.

Binder shall be mylar barrier tape with a 5-mil 0.13 millimeter minimum thickness and a lap of 15 percent of its width.

Barrier tape shall conform to MS MIL-C-13777/GEN and shall be made of mylar (polyethylene terephthalate) with a thickness of 1 mil 0.25 millimeter minimum and 10 percent minimum lap.

Conductor separator shall be fungus-proofed cotton braid conforming to

MS MIL-C-13777/GEN, applied over the binder.

Cable sheath shall be a single layer of polychloroprene conforming to MS MIL-C-13777/GEN, cable grade.

Cable diameter shall be 0.925 inch 23.5 millimeter plus or minus 0.030 inch 0.75 millimeter.

Cable type 46[2PTNo.22] [1PTSINo.14]OS shall have [manufacturer] [year of manufacture] printed on its surface. Marking shall be repeated at intervals of not more than 24 inches 600 millimeter, conforming to MS MIL-C-13777/GEN for method only.

Factory Tests:

Electrical tests shall be conducted on finished cable in accordance with MS MIL-C-13777/GEN. Voltage test shall be conducted at 1,000 volts rms. Minimum insulation resistance shall be 1,000 megohms per 1,000 feet 300 meter.

[Mechanical tests shall be conducted in accordance with MS MIL-C-13777/GEN and shall establish average and minimum values for bond, twist, and impact.]

2.1.3 72(12STSINO.16)OS

Cable type 72(12STSINO.16)OS shall consist of 72 total, conductors with single AWG No. 16 1.25 millimeter (AWG No. 16) conductors, twisted into sextets, with each sextet shielded and insulated, and shall have one overall shield and one overall jacket.

Cable shall be rated 600 volts ac, rms operating voltage and shall be used for instrumentation ground measurement cable routed in ducts above and below grade and in cable trays.

Cable type 72(12STSINO.16)OS shall conform to the following design requirements.

Cable conductors shall conform to MS MIL-C-13777/GEN and shall be made of annealed tinned copper, conforming to ASTM B 33 and shall be Size AWG No. 16 1.25 millimeter diameter (AWG No. 16), conforming to ASTM B 8.

Cable stranding shall be concentric, conforming to ASTM B 8.

Conductor insulation shall be polyethylene, conforming to ASTM D 1248, Type II dielectric, Grade 5, and complying with MS MIL-C-13777/GEN for physical and electrical properties, and shall have minimum 27-mil 0.69 millimeter thick wall.

Conductor color coding shall be conductor No. 1 - black, No. 2 - white, No. 3 - red, No. 4 - green, No. 5 - orange, No. 6 - blue, and shall conform to MS MIL-C-13777/GEN.

Conductor insulation shall conform to MS MIL-C-13777/GEN and shall consist

of clear nylon (polyamide), conforming to ASTM D 4066 and have a minimum extruded thickness of 3-mil 0.075 millimeter.

Conductor sextets shall consist of six singles, twisted with a maximum lay of 6.0 inches 150 millimeter.

Sextet shield braid shall conform to MS MIL-C-13777/GEN and shall be made of tinned copper, conforming to ASTM B 33, applied over the twisted sextet.

Shield braid strand size shall be AWG No. 34 0.16 millimeter diameter (AWG No. 34) with a shield angle of 60 degrees plus 5, minus 10 degrees and shall have a coverage of 90 percent minimum with reverse-lay drawn wire of one or more strands.

Sextet shield insulation material shall be polyvinylchloride (PVC), conforming to MS MIL-W-16878/GEN, with a thickness of 25-mil 0.64 millimeter minimum wall.

Color code (in sextet) shall be 1 black, 2 white, 3 red, 4 green, 5 orange, 6 blue, 7 white with black tracer, 8 red with black tracer, 9 green with black tracer, 10 orange with black tracer, 11 blue with black tracer, and 12 black with white tracer

Cabling shall conform to MS MIL-C-13777/GEN.

Cabling layup shall consist of inner layer three sextets, outer layer, nine sextets.

Cable fillers shall be made of polyethylene filament as required, conforming to ASTM D 1248, Type II dielectric, Grade 5.

Cable filler lay shall have a reverse-lay with a maximum lay of 12 to 16 times the OD of the multiple.

Barrier tape shall conform to MS MIL-C-13777/GEN, and shall consist of mylar (polyethylene terephthalate) with a 3-mil 0.075 millimeter minimum thickness and 50 percent minimum lap.

Overall shield material shall be solid tinned copper with a thickness of 5-mil 0.13 millimeter minimum and a lap of 15 percent of its width.

Barrier tape shall conform to MS MIL-C-13777/GEN and shall consist of mylar (polyethylene terephthalate) with a thickness of 1 mil 0.025 millimeter minimum and lap of 50 percent minimum.

Cable sheath shall conform to MS MIL-C-13777/GEN, and shall consist of one layer of 0.140 inch 3.6 millimeter thick neoprene.

Cable type 72(12STS NO.16)OS shall have [manufacturer] [year of manufacture] printed on its surface. Marking shall be repeated at intervals of not more than 24 inches 600 millimeter, conforming to MS MIL-C-13777/GEN for method only. Maximum cable od shall be 2.25 inches 57.1 millimeter.

Cable shall be electronically tested prior to shipment with an inspection test voltage of 2700 volts and spark test voltage of 5,400 volts. Cable shall also be mechanically tested using the impact, bend, and twist tests.

2.1.4 12 BY 16 PLUS 3 BY 19 ALPETH

Cable type 12 by 16 plus 3 by 19 ALPETH, shall consist of 15 pair total, conductors, with composite video and telephone capability. Cable shall have 12 pairs, AWG No. 16 1.25 millimeter diameter (AWG No. 16), plastic insulated, video conductors, and three pairs,AWG No. 19 36 millimeter diameter (AWG No. 19), telephone, plastic insulated conductors; with an overall aluminum-shielded polyethylene jacket.

Cable shall be rated at 600 volts, rms, or 130 volts (dc) operating voltage and shall be used for instrumentation and base communications applications.

Cable type 12 by 16 plus 3 by 19 ALPETH shall conform to the following design requirements:

Conductor material shall be made of soft or drawn and annealed copper, conforming to ASTM B 3.

Conductor size shall be Type I (video) AWG No. 16 1.25 millimeter diameter (AWG No. 16); Type II (telephone), AWG No. 19 36 millimeter diameter (AWG No. 19), conforming to MS MIL-C-9660 with no stranding or coating required.

Type I; (video) conductors shall be insulated with polyethylene; Type II (telephone) conductors shall be insulated in conformance with MS MIL-C-9660; Grade 4; Type II dielectric shall conform to ASTM D 1248 and MS MIL-C-9660.

Conductor color coding shall consist of the following: Type I, shall conform to MS MIL-C-9660, Table II; Type II, shall conform to MS MIL-C-9660, Table III.

Cable construction shall consist of 15 twisted pairs of conductors, conforming to MS MIL-C-9660 with 12 AWG No. 16 1.25 millimeter diameter (AWG No. 16), Type I (video) pairs and three AWG No. 19 36 millimeter diameter (AWG No. 19), Type II (telephone) pairs. Shielding and taping shall be as required, and shall conform to MS MIL-C-9660. Jacketing shall not be required.

General arrangement of cabling shall conform to MS MIL-C-9660.

Overall cable shield shall consist of 0.008-inch 0.2 millimeter thick low-resistance aluminum shielding tape, longitudinally folded with overlap.

As a minimum, the outside surface of the overall conductor separator shield shall be completely covered by a thin film of specially compounded polyethylene copolymer that forms a hermetic seal along with longitudinal shield and bonds to the cable jacket, preventing moisture penetration between the jacket and the aluminum shield.

Overall cable jacket shall be black high-molecular-weight polyethylene jacket, with 0.111-inch 2.8 millimeter nominal thickness, and 1.4-inch 36 millimeter OD.

Cable Surface printing shall be white neoprene-base ink with the following Legend: 12 by 16 plus 3 by 19 ALPETH 15 twisted pairs [manufacturer] [year of manufacture]. Cable ends shall be marked to identify pulling direction or unit-counting sequence.

The following factory tests shall be performed on each length of cable in accordance with MS MIL-C-9660 unless otherwise specified.

Each Type I cable conductor resistance shall not exceed 23 ohms per mile 1.6 kilometer at 60 degrees F 15 degrees C in accordance with MS MIL-C-9660.

Mutual capacitance between individual conductors shall be not more than 0.058 microfarad nor less than 0.051 microfarad per mile 1.6 kilometer in accordance with MS MIL-C-9660.

Capacitance unbalance between conductors and shields not to exceed 0.50 microfarad per foot 300 millimeter in conformance with MS MIL-C-9660.

Insulation shall be capable of withstanding (ac) test-potential for 2 seconds (maximum instantaneous) 2,800 volts between conductors and between conductors and shield in conformance with MS MIL-C-9660.

The internal echo in a video pair shall be not less than [38] [_____] decibels (dB) from the measuring pulse in conformance with MS MIL-C-9660.

The terminal impedance of Type I and II pairs shall be 125.5 plus or minus 3.5 ohms in conformance with MS MIL-C-9660.

Cable attenuation shall be measured at 1 kilohertz (kHz) and 1 megahertz (MHz) in conformance with MS MIL-C-9660.

2.1.5 7(RG-58C/U)

Cable type 7(RG-58C/U) shall consist of 7 total conductors, with seven coaxial conductors cabled, and one overall jacket.

Cable shall be rated at 1,000 volts (ac), rms operating voltage and shall be used for instrumentation and base communications applications.

Cable type 7(RG-58C/U) shall conform to the following design requirements:

Inner conductor:

Inner conductor material shall be copper wire, 19 strands, conforming to MS MIL-C-17/28 with nominal diameter per strand 0.0071 inch 0.183 millimeter, overall 0.0375-inch 0.953 millimeter maximum conforming to MS MIL-C-17/28.

Cable stranding shall be concentric, 19 by 0.0072 inch 0.183

millimeter, conforming to MS MIL-C-17/28.

Inner conductor coating shall be tin, conforming to MS MIL-C-17/GEN.

Inner conductor insulation shall be polyethylene, Type II, Class M, conforming to MS MIL-C-17/GEN and ASTM D 1248.

Outer conductor:

Outer conductor material shall be single braid AWG No. 36 0.127 millimeter diameter (AWG No. 36) tinned copper, conforming to MS MIL-C-17/GEN with a polyethylene jacket, Type II, Class M, black, 22-mil 0.56 millimeter minimum wall thickness, conforming to ASTM D 1248, with 0.199-inch 5.05 millimeter maximum od. Color coding is not required.

Cabling:

Cable type 7(RG-58C/U) shall be cabled as follows:

The inner layer shall consist of, one single layer, and the outer layer shall consist of six singles. Cables shall have unidirectional-lay with length of lay varying from 8 to 16 times the od of the layer.

Cable fillers shall be polyethylene, Type I, Grade 2 filament, conforming to ASTM D 1248.

Binder tape shall be mylar (polyethylene terephthalate), with 2-mil 0.05 millimeter minimum thickness, applied with 50-percent minimum lap, conforming to MS MIL-I-631.

Conductor separator shall be cotton braid conforming to MS MIL-C-13777/GEN.

Overall jacket shall be with neoprene, 0.080-inch 2.03 millimeter minimum thickness, conforming to MS MIL-C-13777/GEN with 0.844-inch 21.4 millimeter maximum od.

Surface cable printing shall be white neoprene-base ink with the following Legend: 7(RG-58C/U) (manufacturer) (year of manufacture).

The following factory tests shall be performed on the cable prior to shipping:

Certified reports of factory tests shall conform to MS MIL-C-17/GEN.

Dielectric strength shall be 5,000 volts rms, minimum, conforming to MS MIL-C-17/GEN.

Capacitance shall be measured at 1 kHz or at 1 MHz, conforming to MS MIL-C-17/GEN.

Attenuation shall be 14.0 dB per 100 feet 30 meter, maximum, at 400

MHz, conforming to MS MIL-C-17/GEN.

Impedance shall be 50.0 plus or minus 2.0 ohms, conforming to MS MIL-C-17/GEN.

2.1.6 T-43

Cable type T-43 shall consist of 2 total, conductors, with AWG No. 19 36 millimeter diameter (AWG No. 19), plastic insulated, individual conductors twisted into one pair and shall be double flexible, copper shielded, abrasion resistant and plastic jacketed.

Cable shall be rated at 600 volts (ac), rms operating voltage and shall be used for instrumentation and base communications applications.

Cable type T-43 shall conform to the following design requirements:

Conductor material shall be made of annealed copper, conforming to ASTM B 3, and shall be Size AWG No. 19 36 millimeter diameter (AWG No. 19), conforming to ASTM B 258.

Stranding and coating shall not be required.

Cable insulation shall be polyethylene, with 35-mil 0.89 millimeter minimum wall thickness, Type II, Class M, conforming to ASTM D 1248.

Conductor color coding for circuit identification shall be one blue conductor and one white conductor without a cable sheath.

Cable construction shall consist of 2 conductors twisted into one pair, with a solid polyethelene belt extruded over the pair and filling the interstices.

Cable shield shall consist of 2 silver-coated braided shields, AWG No. 34 0.16 millimeter diameter (AWG No. 34), each shield having 85-percent minimum coverage, conforming to MS MIL-C-13777/GEN without tape.

Cable jacket shall be black PVC conforming to MS MIL-C-17/GEN with 0.42-inch 10.7 millimeter approximate OD.

The following factory tests shall be performed on the cable prior to shipping:

Certified reports of factory tests shall conform to MS MIL-C-17/GEN.

Conductor resistance shall be 46 ohms per mile 1.6 kilometer, maximum, at 68 degrees F 20 degrees C.

Mutual capacitance shall be 0.067 microfarad per mile 1.6 kilometer, nominal.

Dielectric strength shall be 5,000 volts rms at 60 hertz between conductors for 2 seconds.

Attenuation shall be 12.9 dB per mile 1.6 kilometer, nominal, at 1 MHz; 25.9 dB per mile 1.6 kilometer, nominal, at 4 MHz; and 41.5 dB per mile 1.6 kilometer, nominal, at 10 MHz.

Characteristic impedance shall be 124 plus or minus 5 ohms.

2.2 COAXIAL CABLES

Coaxial cables shall conform to the following specifications, as applicable:

RG-214 - MS MIL-C-17/75

RG-318/U - MS MIL-C-22931/11

RG-319A/U - MS MIL-C-22931/13

RG-366/U - [Andrews Catalog] [_____], or an approved similar product

Connectors at both mating ends of cables shall reduce to Type N female, with standard O-rings, suitable for temperature range of minus 60 degrees F to plus 275 degrees F 16 degrees C to plus 135 degrees C. Connectors shall be supplied with 1/8-inch 3.2 millimeter iron pipe size (ips) threaded gas inlet port. Connectors shall make a positive grip to the cable sheath without distortion and shall result in a pressure-tight seal. Connectors shall be compatible with cable ends.

2.3 WAVEGUIDES

2.3.1 Rectangular Waveguides

Waveguides shall be made of oxygen-free, high-conductivity copper conforming to MS MIL-W-85/GEN and shall be bright-dip processed. Exterior finish shall consist of a zinc-chromate primer and light-gray enamel paint conforming to MS MIL-E-15090.

Waveguides for the KU-band shall be [Andrews Catalog] [_____], or an approved similar product. Attenuation shall not exceed 6.5 dB per 100 feet 30 meter.

2.3.2 Rectangular Flanges

Waveguide flanges shall be choke-and-cover configuration. Flanges shall be machined from brass and conform to MS MIL-F-3922/GEN. Flanges shall be silver plated. Rectangular flanges shall be attached to rectangular waveguide sections by silver brazing. Choke flanges shall be equipped with neoprene O-ring gaskets suitable for pressurization up to 5 pounds per square inch, gage (psig) 35 kilopascal of gaseous nitrogen.

2.3.3 Elliptical C-Band Waveguides

Flexible-twistable sections of waveguide shall be constructed of convoluted thin-wall copper such as [Andrews Catalog] [_____], or equivalent. Flexible-twistable sections of waveguide shall have a minimum bend-radius of 17 inches430 millimeter in the E-plane and 41 inches 1040 millimeter in the

H-plane and a capability of plus or minus 0.50 degree of twist per foot 300 millimeter of length.

Waveguides for the C-band shall be [Andrews Catalog] [_____], or an approved similar product.

2.3.4 Elliptical KU-Band Waveguides

Flexible-twistable sections of waveguides shall be constructed of convoluted thin-wall copper such as [Andrews Catalog] [_____], or an approved similar product. Flexible-twistable sections of waveguide shall have a minimum bend-radius of 6 inches 150 millimeter in the E-plane and 13 inches 330 millimeter in the H-plane and a capability of 2-degrees twist per foot 300 millimeter of length. Flexible-twistable sections of waveguide shall be furnished with a molded neoprene jacket.

2.3.5 Elliptical Waveguide Connectors

Elliptical waveguide connectors shall be [Andrews Catalog] [_____], or an approved similar product.

2.3.6 Hangers and Hardware

Waveguide hangers and hardware shall be designed to support the waveguide in any position. Hangers shall be made of high-strength fungus- and moisture-proof molded plastic. Clamping bolts, nuts, and washers shall be 300 series corrosion-resistant steel, unless otherwise indicated.

Spring-type waveguide hanger shall consist of sliding hanger connected through a suitable spring to a fixed hanger solidly attached to the waveguide. Spring tension shall be adjusted to carry the full weight of the vertical waveguide down to the next spring-type hanger.

PART 3 EXECUTION

3.1 INSTALLATION OF INSIDE CABLES

Care shall be exercised when handling and storing reels of cable to prevent damage to the cable. Cable with dents, flat spots, or other sheath distortions shall not be installed. Cable ends shall be sealed until cables have been installed. Cable requiring pressurization during shipping and storage shall be checked to ensure integrity of pressurization.

Immediately after cable placement, temporary tags with the cable number and type shall be attached to each end of each cable section.

Cables and equipment shall be supported and secured as indicated. Where the specific method of support is not indicated, adequate supports and fasteners shall be used to secure cables and equipment in position. Metallic supports and fasteners shall have a corrosion-resistant finish.

Cables shall be provided in continuous lengths as required to accomplish the required installation without splices from termination to termination, except where field splices are specifically indicated. When it is

necessary to make any splices other than those indicated, the Contractor shall submit reasons and the proposed splicing techniques for approval. Splices, when approved, shall be provided at no additional cost to the Government.

Caution shall be used when bending cable to avoid kinks or other damage to sheath. Bend radius shall be as large as possible with a minimum of not less than 10 times the od of the cable. Minimum radii shall be increased when necessary to meet cable manufacturer's recommendations.

3.1.1 Raised Floors and Cable Trays

Instrumentation and communications cables shall not be installed in the same cable tray with ac power cables.

Cables placed in cable trays or under raised floors shall be installed in a neat and orderly manner and shall not cross or interlace other cables except at breakout points.

Instrumentation and communication cables shall be routed under raised floors as indicated. Cables shall be placed under raised floors without crossing or interlacing cables, except at breakout points. Installation of cables under raised-floor areas shall be closely coordinated with existing cables and utilities installed in these areas. New cables shall be routed as required to avoid interferences with existing utilities in the raised-floor areas. Cables routed under false floors shall be routed parallel to cabinet or rack bay fronts and walls and under corridor areas created by racks and equipment in lieu of the routing and location indicated. Unterminated cables shall be laid in the specified routing and location indicated. Unterminated cable ends shall be cleared, capped, and sealed. There shall be no coiled cable length under raised-floor areas unless specifically indicated.

Cables in vertical trays shall be individually retained with [Ty-Rap straps] [_____], or an approved similar product, a maximum of 6 feet 1800 millimeter on center.

3.1.2 Boxes and Enclosures

Each conductor of each cable shall be terminated on terminal blocks or on connectors as indicated and scheduled, except where specifically noted that terminations are future or where the cable is indicated to be coiled cable. All terminations shall be provided even though each conductor of each cable is not shown on the schematics of the distributors and the termination details.

Termination procedure for any cable within a distributor or other wiring enclosure shall not be started until all cables have been pulled into the enclosure. These cables shall then be terminated as indicated and as described herein. Installation of harness assemblies shall not be started until the completion of the termination of the applicable incoming cables as described above.

Where cables are pulled into existing or previously installed distributors,

the existing hardware shall be adequately protected against damage. Any damage to the existing hardware shall be repaired in an approved manner and at no additional cost to the Government.

Cables, conductors, and shields shall be terminated as indicated. Terminals and connectors shall be installed using only tools specifically recommended by the hardware manufacturer and shall be of the type that requires a specific force to perform the crimp and release of the handles of the tool for the next crimp. Installation procedure shall follow the manufacturer's installation directions.

Tying and lacing multiconductor cables in the terminal distributors shall be as indicated. Groups of conductors shall be bound by means of plastic fasteners similar to [Thomas and Betts Co. self-locking Ty-Rap ties] [_____] or an approved similar product. These fasteners shall be placed every inch 25 millimeter along the main harness and cable, and adjacent to each conductor leaving the bundle at the breakout point.

Cables shall be supported as near to the termination point as possible to prevent strain due to the weight of the cable from being transmitted to the individual conductors where they are connected to terminal blocks or to connector terminations. In terminal distributors, the cables and the cable-harness assemblies shall be supported horizontally to their respective terminal-block mounting channels. Supports shall be spaced a maximum of 6 inches 150 millimeter on center, with a support located immediately adjacent to and on each side of the breakout of the conductors from the cable. Supports shall be similar to [self-locking Ty-Rap straps] [_____] or an approved similar product and shall be securely bolted to the horizontal mounting channel. Care shall be taken not to have any of the cable shields or the conductor shields grounded to the terminal distributor frame, especially at the points of cable supports. Where cables with overall shields or with individually shielded but not jacketed conductors or pairs are terminated on terminal blocks, the terminal-block mounting channel shall be adequately insulated with insulating tape to maintain the isolation of the shields from ground.

Cables shall be identified by their cable number at cable termination points, including where cables leave cable trays, enter or leave false floors, and before they enter into terminal enclosures. Identification marker tapes shall be as indicated.

3.1.3 Bonding and Grounding Systems

Cables shall be grounded as specified in Section 16065, "Secondary Grounding," unless otherwise indicated. The overall shield of cables installed shall be grounded at each terminal point.

3.1.4 Connector Cable and Harness Assemblies

Fabrication and testing of the connector cable assemblies and harness assemblies shall be in strict accordance with this specification. No such departure shall be made without prior written approval.

Harness assemblies shall be fabricated from unspliced conductors as

indicated.

Harness conductors or cables shall be bound together using plastic or nylon harness straps on approximately 1-foot 300 millimeter spacing to prevent tangling of the cables.

3.2 INSTALLATION OF COAXIAL CABLES AND WAVEGUIDES

Each cable or waveguide run shall be identified as indicated.

3.2.1 Coaxial Cables

Structural supports for coaxial cables shall be installed straight and plumb and as indicated. Supports shall be installed to permit running of the transmission lines where indicated. Coaxial cables shall be supported securely at bulkhead plates and terminal distributors.

There shall be no bends, offsets, or flexible sections other than those indicated and approved.

Coaxial cable shall be assembled as indicated.

Coaxial cable runs shall be continuous from termination, with no connectors between the coaxial switch connector and checkout-room termination, except as indicated.

Coaxial cable shall be terminated and Type N connectors attached in accordance with the cable manufacturer's recommended procedures. Contractor shall furnish the cable manufacturer's published terminating procedures. Upon approval, these procedures shall be used as the basis for installation of all coaxial cable connectors.

Coaxial cables shall be attached to supports with two turns of 0.5-inch 13 millimeter wide corrosion-resistant steel strap secured with fasteners specifically designed for this purpose. Strapping material shall be [Wraplock] [_____], or an approved similar product. Cables shall be attached to supports at intervals not exceeding 5 feet 1500 millimeter.

Bending radius of coaxial cable shall be not less than manufacturer's published minimum bend radius under any circumstances. When it is necessary to bend cable to a radius of less than 24 inches 600 millimeter, an approved pipe-bending device shall be used to form the cable. There shall be no evidence of wrinkling of cable conductors or cable sheath.

Pressurizing tubing and fittings shall be installed in a neat and workmanlike manner. Type N connectors shall be oriented with gas ports in such a position that an orderly arrangement of tubing may be effected.

Desiccant method shall be used for drying out connections or removing moisture prior to splice closure. Boiling paraffin method shall not be used.

On indoor connections, polyethylene tape shall be applied with a half-lap to completely cover exposed metal portions of coaxial cable and terminated

connectors.

On outdoor connections, after the connectors are joined, [Dow Corning DC-11 silicone lubricant] [_____], or an approved similar product, shall be applied to cover the complete surface of the connectors and a minimum of 2 inches 50 millimeter on each side of the connector hubs where the cable mating occurs.

Connection shall be sleeved using an appropriate size to accommodate the cable jacket and connectors used and to completely encapsulate the connection.

Heat-shrinkable tubing shall be [Raychem Type [TCS,] [WCS,] [WRS,]] [_____] or an approved similar product. Heat-shrinkable tubing shall be installed in accordance with the manufacturer's instructions.

Excess silicone lubricant shall be wiped clean from the outer surface of the cable jacket.

3.2.2 Waveguides

Structural supports for waveguides shall be installed straight and plumb and where indicated. Supports shall be installed to permit running the waveguides as indicated. No bends or offsets shall be added to those indicated without approval.

Waveguides shall be assembled as indicated and in accordance with the manufacturers' instructions.

Waveguide sections shall be complete with flanges attached at each end by the manufacturer. No flanges shall be installed on waveguide tubing in the field. It shall be the Contractor's responsibility to determine the exact dimensions of required waveguide sections prior to the release of shipment. Required adjustments shall be made.

In all cases, a cover flange shall be installed against a choke flange on the adjacent section.

Precautions shall be taken at the end of each work period to ensure that no foreign material enters or remains in the waveguides. Coverplates designed for this purpose will be considered acceptable.

Waveguides shall be handled very carefully. Deformed tubing or flanges shall be replaced.

Gaskets for waveguides shall be given a light coating of [Dow Corning DC-4 silicone lubricant] [_____] or an approved similar product before installing. This coating shall wet the complete surface of the gasket, without excess.

Alignment of straight runs of waveguides, including bolted-up flanges, shall be true within 1/2 inch per 50 feet 15 millimeter per 18 meter of run, with no strain on waveguide hangers other than the weight of the waveguide itself.

Waveguide supports shall contain waveguides only and shall not support conduit or other transmission mediums.

3.2.3 Grounding

Appropriate grounding kits provided by the manufacturer of the coaxial cable and waveguides shall be installed in accordance with the manufacturer's specifications and as indicated.

3.3 INSTALLATION OF OUTSIDE PLANT COMMUNICATION CABLES

3.3.1 Cable Placement

Adequate care shall be exercised when handling and storing reels of cable to prevent damage to the cable. Cable with dents, flat spots, or other sheath distortions shall not be installed.

Cable to be maintained under gas pressure after installation shall be maintained under pressure at all times during placement. Gas pressure of each cable section shall be measured before and after placement to confirm the gastight integrity of the sheath.

Lengths of pressurized cable remaining after a portion is cut off shall be resealed immediately and recharged with dry gas.

Immediately after placement, temporary tags with the cable number and pair count shall be attached to each end of each cable section. The ends of cables containing video pairs shall be checked to ensure that the green or yellow markings are intact. When the markings are missing, green or yellow tape, as applicable, shall be attached to the cable end.

Cables and equipment shall be supported and secured as indicated. Where the specific method of support is not shown, adequate supports and fasteners shall be used to secure cables and equipment in position. Metallic supports and fasteners shall have a corrosion-resistant finish. Cables and equipment installed in exterior locations shall be secured so that they cannot be dislodged or damaged by winds up to 125 miles 200 kilometer per hour.

Cable splices shall not be made in locations not indicated or specified herein. Cable splices in ducts shall not be allowed.

Composite video-telephone cable sections to be spliced shall be installed with the same direction of lay to avoid video-pair crossover splicing. The cable ends shall be marked to indicate the direction of video-pair count. Cable reels shall also be marked accordingly. When the video-pair count at the outer end of the reel is counterclockwise, the reel shall be marked CCW in green paint and the outer end of the cable shall be marked with green paint or a band of green tape. The inner end shall be marked with yellow. When the count of the video pairs at the outer end of the reel is clockwise, the cable reel shall be marked CW in yellow paint; the outer end of the cable shall be marked yellow, and the inner end shall be marked in green. Cables shall be so placed that at splicing points one cable end is

green and the other cable end is yellow.

Caution shall be used when bending cable to avoid kinks or other damage to the sheath. Bend radius shall be as large as possible with a minimum not less than 10 times the od of the cable. Minimum radii shall be increased when necessary to meet cable manufacturer's recommendations. Bending operations in manholes and vaults shall be performed in accordance with the procedures and instructions of the manufacturer. Cable bending shoes shall be used at duct or conduit ends when bending cable exiting a duct or conduit. Bending shoes shall remain in place until racking, splicing, and tying is completed. Cables shall not rest against the edge of the duct or conduit mouth.

Duct or conduit assignment for individual cables is indicated. Cables shall not be placed in ducts or conduits other than those indicated.

Assigned ducts and conduits shall be cleaned and tested for alignment before pulling in cable.

The number of unspliced cable ends in a manhole, vault, or terminal room shall not exceed eight ends in manholes or four ends in vaults or terminal rooms. When a larger number of cables is to be placed, the cables shall be pulled, racked, and spliced or terminated in an order that will not exceed the above limitation. End slack in excess of that needed to properly rack and splice or terminate the cables shall not be pulled into manholes, vaults, or terminal rooms. End slack should provide [_____] [5] feet [1500] millimeter overlap for splicing.

When a duct or conduit has an appreciable curve and conditions permit, the cable reel shall be set up at the end nearest the bend and the cable pulled from the opposite end. Otherwise, the cable may be pulled from the most convenient end. Contractor shall adhere to the direction of placement for video cables.

Pulling lines shall be attached to cable ends fitted with factory-installed pulling eyes. Cables not equipped with a pulling eye shall not have the pulling line attached to the cable end by means of a cable grip. Core hitches shall not be used.

Cable reels shall be located and aligned so that the cable is payed off the top of the reel into the duct or conduit in a long, smooth bend without twisting. Cable shall not be pulled from the bottom of a reel or subjected to reverse bends from those formed by factory reeling. A cable-feeder guide of proper dimensions shall be used at the mouth to guide the cable into the duct or conduit.

Rigging shall be set up at the pulling end so that the pulling line and cable exit on a line parallel with the duct or conduit to prevent either from rubbing against the edge or mouth. Cable ends shall not be pulled around sheave wheels. When the sheave or pulley cannot be positioned to obtain sufficient cable end slack for proper racking and splicing with the pulling line attached to the end of the cable, a pulley shall not have the pulling line attached to the cable end by means of a cable grip. Core hitches shall not be used.

Unterminated cables shall be laid in the specified routing and location as indicated. Unterminated cable ends shall be cleared, capped and sealed. When approved by the Contracting Officer, a lubricant may be applied to facilitate cable-pulling. Lubricant shall be compatible with and intended for use with lead-sheathed, plastic-sheathed, and rubber-sheathed cables. Soap and grease lubricants shall not be used.

Equipment and the pulling setup shall be carefully checked to minimize interruptions once pulling begins. Cable shall be pulled as far as possible without stopping until the required amount of cable has been placed. When the pulling operation must be halted before the pull is completed, the tension of the pulling line shall not be released. When pulling is resumed, the inertia of the cable shall be overcome by increasing the tension in small steps a few seconds apart until the cable is in motion. Cable shall be payed off the reel by rotating the reel in the feed direction at the rate of pull; the cable shall not be stripped off the reel by pulling.

Cable shall be carefully inspected for sheath defects or other irregularities as it is payed off the reel. When defects are detected, pulling shall stop immediately and the cable section shall be repaired or replaced at the discretion of the Contracting Officer. Communications shall be maintained between pulling and feed locations so that pulling can be stopped instantly, when necessary.

Continuous cable pulled-through two duct sections without splicing in an intermediate manhole) (pull-throughs) shall not be made unless specifically indicated. When making authorized pull-throughs, a cable guide shall be used in the intermediate manhole to guide the cable into the second duct section. Proper rigging shall be used in the intermediate manhole to keep the pulling line and cable aligned with the exit duct to prevent the line or cable from rubbing against the edge of the duct. Cables in pull-through manholes shall be set up and racked before the cable ends in adjacent manholes are set up and racked. A split cable grip shall be used to pull in sufficient racking slack from adjacent manholes.

Cable ends pulled into manholes, vaults, or terminal locations that are not to be racked or otherwise permanently positioned shall immediately be tied in fixed positions with muslin ties to prevent damage to the cables and to provide adequate working space. After final racking and splicing, plastic-sheathed cables in manholes and vaults shall be secured in place with lashed cable supports or with lashing wire and shims. Cables in other locations shall be secured in the manner indicated. When securing details are not indicated, the cables shall be secured in a manner that will maintain the cables in the required position without damage to the cables.

Ducts and conduits in which cables are placed shall be sealed with split, soft expandable-rubber conduit plugs with galvanized-steel plates and bolts at the locations indicated.

Excavation required to install the cables and equipment indicated shall be performed.

Unless otherwise indicated, direct-buried cables may be placed by either plowing or trenching and shall be placed a minimum of 30 inches 770 millimeter below grade.

Underground utilities in the path of cable burial operations shall be located and exposed or the depth determined by other means before beginning trenching or plowing.

Communications cables shall not be installed in the same trench with electrical power cables. A minimum separation of 12 inches 300 millimeter shall be maintained between buried communications cables and power cables. Where buried communications cables must cross power cables, the communications cables shall, where possible, be placed above the power cable. Creosoted wood or concrete separators shall be placed between communications and power cables at crossover points.

Trenches shall be wide enough for proper cable laying and backfilling. The bottom of the finished trench shall be filled with no less than 3 inches 75 millimeter of sand or fine soil that will not damage the cable sheath. Cables shall be placed in one trench on top of the sand cushion.

Trench backfilling shall be accomplished by placing 3 inches 75 millimeter of sand or fine soil over the cable and hand tamping it over and around the cable. The balance of backfilling shall be accomplished in 6-inch 150 millimeter layers, each layer being compacted to a density at least equal to that of the adjoining soil before the next layer is placed. Topsoil and sod shall be replaced and as nearly as practical restored to the original condition. Excavated materials not required or suitable for backfilling shall be disposed as directed by the Contracting Officer.

Cable plowing operations shall be in accordance with the operating procedures provided by the cable plow manufacturer and the requirements specified herein. Plowing operations shall be observed continuously to ensure that the cable is not damaged during placement and that proper depth is maintained.

Cable crossing under roadways or other pavement shall be made by jacking a pipe where practical. When it is necessary to break the pavement, permission shall be obtained from the Contracting Officer before proceeding. Immediately upon completion of the cable-sleeve placement, the roadway or other hardstand shall be restored to the original condition.

Where buried cable enters the end of an underground pipe or conduit, [Ductseal] [_____] or an approved similar product material shall be packed between the cable and the inside of the sleeve end to prevent damage to the cable sheath and entrance of dirt into the sleeve.

3.3.2 Cable Splicing

Cables shall be spliced in accordance with the manufacturer's approved procedures and as specified herein and indicated. Unless otherwise specified herein or indicated, the Contractor shall adhere to the requirements, procedures, and constraints in the manufacturer's approved procedures for splices being performed.

Conductor joints in telephone-pair splices shall be made by the twist-and-solder method. Double-wall cotton sleeves shall be used to insulate paper- or pulp-insulated telephone-conductor splices.

The desiccant method shall be used for drying out splices or removing moisture prior to splice closure. Boiling-paraffin methods shall not be used.

Lead sleeves with an inside diameter of 3 inches 75 millimeter or larger shall be extra strength with a 1/4-inch 6.35 millimeter wall.

Conductors shall remain in their correct color groups or units except when required for defective pair transpositions.

Lead-sleeve splice enclosures shall be used on lead-sheathed and Stalpeth-sheathed cables. Auxiliary lead sleeves installed in accordance with the manufacturer's instructions shall be used on all splices in Stalpeth-sheathed cable.

Heat-shrinkable cable sleeving such as [Raychem Type [TCS,] [WCS,] [WRS,]] [_____] or an approved similar product shall be used to enclose the auxiliary sleeve in the outer cable jacket.

Heat-shrinkable sleeving shall be installed in accordance with the manufacturer's instructions.

3.3.3 Pressurization

Paper-insulated telephone cables, composite telephone/wideband cables, and other cables indicated shall be pressurized by a continuous-flow dry-air system at 9.4 psig 65 kilopascal minimum. All such cables shall be pressurized and tested for pressure tightness prior to acceptance by the Government.

Cables indicated to be pressurized after installation shall be maintained under a nitrogen or dry-air pressure of not less than 9.0 psig 62 kilopascal at all times before, during, and after installation, except when cable cutting or splicing is in progress.

Dry-air supply and pressure monitoring and control facilities of the types, sizes, and quantities indicated shall be provided and installed at the locations and in the manner indicated. Where particular installation details or hardware identification are not indicated, materials and installation practices shall be in accordance with the equipment manufacturer's recommendations. Air-source equipment shall be verified to operate properly before being connected to the cables.

Gas-pressure blocks shall be provided in cables at the points indicated. Pressure blocks shall be made with resin compounds compatible with and recommended by the compound manufacturer for use with the insulation type (plastic or paper) in the cable to be blocked. Pressure blocks shall be not less than 30 inches 770 millimeter from any splice. Pressure blocks in terminating cables shall be made in the vertical portion of the cable when

practical.

Pressure Test valves and bypass valves in manholes shall be mounted on the manhole collar as indicated.

Contactors and contactor terminals in manholes shall be mounted on manhole side-walls as indicated.

Pressure-test valves, bypass valves, contactors, and contactor terminals on direct-buried cable shall be mounted above ground on posts as indicated.

The contactor pair in all contactors or contactor terminals on a given cable sheath shall be connected in full multiple to the lowest-count telephone pair in the sheath.

The talking pair in contactor terminals shall be connected to the second-lowest count pair in the cable to which it is connected. In composite telephone/wideband cables containing only three telephone pairs, the telephone pairs shall be terminated at the ends of the cable with counts 1, 2, and 3, with the tracer pair being count 3. Contactor pairs connected to the cable shall be connected to pair 1. Talking pairs in contactor terminal connected to the cable shall be connected to pair 2.

Each pressure contactor shall be adjusted to operate (contact closure) when the cable pressure at the contactor drops to 6.0 plus or minus 0.5 psig 41 plus or minus 3.5 kilopascal. When adjusting the contactor operating point, pressure shall be monitored at the test valve on the contactor and gas shall be fed or bled through the associated test valve connected to the cable-splice closure. Each contactor and contactor terminal shall be shown to operate at the specified operating pressure.

Type C pressure-testing flanges shall be installed in cable splice sleeves not equipped with pressure-testing valves. Flanges shall be sealed with Type C flange plugs. This requirement does not apply to direct-buried splices unless specifically indicated.

Completed cable installation shall be tested to verify the pressure tightness of pressurized cables and associated pressurization hardware. Cable system shall be pressurized at a stabilized pressure of 9.0 psig 62 kilopascal and the pressure source shut off. Meter panel valves and crossover-bypass valves shall be closed so that maximum isolation between cables allowed by the pressurization system configuration is attained. After the pressure source has been shut off, pressure readings shall be made and recorded at each end of each cable. Pressure readings shall be made at test valves in manholes for underground cables and at test valves connected to buried splices for direct-buried cable. Pressure readings made at test valves in manholes shall be corrected to the equivalent pressure at 60 degrees F 16 degrees C. The ambient temperature used in making the temperature corrections shall be that measured in the manhole with a thermometer suspended near the bottom or immersed in the water if the cable on which the measurement is being made is under water. No temperature correction is necessary for direct-buried cable. Pressure readings shall be made with a pressure gage or manometer with an accuracy of 0.025 psi 0.17 kilopascal or greater. The same gage and thermometer shall

be used for all test measurements at any given test point. A minimum of 96 hours after the initial pressure readings were made, pressure measurements shall be made at the same test points and in the same manner as the initial readings. When the pressure in any cables has dropped more than 1.0 psig 6.9 kilopascal during the 96-hour period, those cables are unacceptable. Pressure leaks shall be located and repaired and the 96-hour pressure test repeated. Cables shall exhibit a pressure loss of less than 1.0 psig 6.9 kilopascal during the specified 96-hour test prior to acceptance.

3.3.4 Bonding and Grounding

Bonding and grounding shall be as specified in Section 16065, "Secondary Grounding," unless otherwise indicated.

3.3.5 Terminations

Contractor's wire-wrapping procedure shall be approved before wire terminations are to begin.

Solderless wire wraps shall consist of a minimum of 5 turns of AWG No. 22 0.63 millimeter diameter (AWG No. 22) wire wrapped under tension around a post having four sharp corners. The first turn shall be insulated wire and the remaining turns, a minimum of four, shall be bare wire. The air gap between adjacent wrapped posts shall be not less than 0.050 inch 1.3 millimeter. Spacing between turns shall not exceed one-half the diameter of the insulated wire. There shall be no overlapped turns, and the final turn end shall not extend more than two times the bare conductor diameter from the wrap post. The first turn shall be positioned adjacent to the post base so that wire routing does not unwrap the insulated turn.

Wrapped connections shall meet the above criteria and shall be free of nicks, mars, and damage to previously routed wire and any other defect. Defective wraps shall be repaired in an approved manner.

Video-cable terminations shall be as indicated.

3.3.6 Tagging and Marking Cables and Equipment

Identification tags and markings shall be placed on cables, termination equipment, and pressurization equipment as indicated and specified herein.

Identification tags placed on cables, cable stubs, pressure-test valves, bypass valves, contactors, and contactor terminals shall be lead tags installed as indicated. Lead tags shall be marked by die stamping.

A minimum of one lead tag shall be attached to each cable and cable stub in each manhole, cable vault, and the terminal point. Tags on cables and cable stubs shall be marked to indicate the quantity and wire gage of pairs and the cable number and pair count of the associated cable or stub.

Tags on pressure test valves, bypass valves, contactors, and contactor terminals shall be marked to indicate the cable number and pair count of the associated cable.

Cable terminals, terminal enclosures, terminal bays, distributing frames, protector assemblies, meter panels, and other equipment not tagged with lead tags shall be marked by rubber stamping or by stenciling with contrasting-colored ink or paint. Methods and materials used in marking shall be in accordance with TO 31-10-27. Ink-stamp markings in exterior equipment shall be covered with a coat of clear varnish, shellac, or plastic.

Vertical numbers, cable numbers, and pair count shall be marked on the designation boards on the vertical side of floor-mounted distributing frames and wall-mounted frames as shown in TO 31-10-27.

Protector assemblies mounted on distributing frames shall be marked with the cable-pair count. Every tenth pair shall be identified. Locations of markings shall be in accordance with the manufacturer's recommendations.

Line terminal blocks on distributing frames shall be marked with the cable number and the first and last pairs of the pair count terminated thereon. Markings shall be placed as shown in TO 31-10-27.

Cable terminals (terminal blocks and binding post chambers) shall be marked with the cable number and the first and last pairs of the pair count terminated thereon. Pair numbers shall be stamped on the front face of fanning strips as shown in TO 31-10-27.

Video-cable terminal bays, video-cable terminals, and cable-terminating cabinets shall be marked as indicated.

The individual air-rate indicators on air-meter panels shall be marked to show the cable number and pair count of the cable fed by each air-rate indicator.

3.4 FIELD TESTING

3.4.1 Test Equipment

Insulation-resistance tests shall be performed with a 500-volt insulation-resistance test set.

Use of auxiliary test boards, panels, or other special equipment to facilitate the testing procedure is optional, subject to approval. Equipment shall not cause any appreciable change in the actual cable measurements being made and shall be designed to permit ready verification of the internal circuits and components.

Test equipment shall be calibrated by a certified testing company every [80] [_____] days unless required sooner due to damage or inaccuracy. Standards for calibrating shall be as listed by the National Bureau of Standards, and each item of test equipment shall display a current calibration sticker.

3.4.2 General Acceptance Testing

3.4.2.1 Preinstallation Testing

Government-furnished cables shall have the following functional tests performed by the Contractor upon receipt of these cables and prior to his acceptance of these cables for installation. Tests shall be performed in accordance with the approved acceptance-test plan.

Continuity tests: These tests shall be performed on conductors and shields for all cable types. Continuity tests shall be completed prior to insulation-resistance testing.

Insulation-resistance tests: These tests shall be performed with a 500-volt insulation-resistance test set on all cable types. The insulation resistance values shall as specified on the drawings.

3.4.2.2 Installed-Cable Testing

After installation, terminated cables shall have the validation tests performed as described hereinafter, in accordance with the approved acceptance-test plan. Cables left unterminated shall be temporarily terminated, tested, and the temporary termination removed. End-to-end testing of the instrumentation cables shall include the harness assemblies.

Continuity tests: This testing includes tests for shorts, grounds, crosses, and transpositions and shall be performed on the conductors and shields of all installed cables. Continuity tests shall be completed prior to insulation-resistance testing.

Conductor resistance tests: These tests shall be performed with a Wheatstone bridge on the conductors for all installed cables. These tests shall verify that the terminations have been properly made. The maximum reading for any one conductor shall be determined from the following formula:

R(max) = R(wire) plus 0.02 ohm per connection point in circuit

Where:

R(max) = maximum resistance (in ohms) allowed

R(wire) = resistance of conductor at room temperature calculated from the cable specification

0.02 = ohm per connection point includes contact resistance of mating test connector. A connection point in a circuit is defined as each lugged junction or each mating-connector contact pair.

Insulation-resistance tests: These tests shall be performed on all cable types with a 500-volt insulation-resistance test set. The insulation-resistance values shall be as specified on the drawing.

Attenuation tests: These tests shall be performed on coaxial cables or

the coax conductors of composite cables. Attenuation tests shall be performed at the frequencies and by the methods specified in the cable specifications. Acceptance-test values shall be as specified in the cable specifications.

Pulse tests: These tests shall be performed at the terminations of each conductor of instrumentation cable and harnessed conductors after installation of terminal lugs. Method of testing and acceptable values shall conform to the approved test plan.

3.4.2.3 Rejection and Resubmittal

Any harness assembly that fails examination or acceptance test will be rejected.

Rejected assemblies may be resubmitted at the discretion of the Contracting Officer after corrective action has been taken. The number and types of rejects will be basis for permitting resubmittal. Reworked assemblies shall be completely retested and be accompanied by a report that details previous rejections and corrective action taken.

Instrumentation and communication cables shall be tested as provided in applicable referenced specifications and as indicated.

Cable tests shall be comparable in methods and accuracies to those contained in referenced specifications and shall include the methods and specifications contained herein.

Government-furnished cable that fails acceptance tests as specified herein shall be examined for invasion of moisture at the cable ends. When the cable ends are found to be unsatisfactory, the Contractor shall cut back 2 feet 600 millimeter from each end and retest the cable at no additional cost to the Government.

An inspection tag shall be attached to each assembly certifying conformance to the requirements as indicated.

3.4.3 Testing Coaxial Cables and Waveguides

3.4.3.1 Pressurization Testing Cable and Waveguide

Gaseous-nitrogen pressurization of coaxial cable and waveguides shall be provided as indicated.

Pressure windows shall be provided and installed on ends of each waveguide run in each checkout room. Pressure windows shall be the type with choke flange on one side and cover flange on the other.

Pressure adapters shall consist of a short-flanged straight section equipped with threaded hub and 1/8-inch 3.2 millimeter ips female thread.

3.4.3.2 Leakage Test

Pressurization leakage test shall consist of pressurizing the transmission

line to 5 psig 35 kilopascal and sealing the line from the others by closing all valves at the pressurization manifold. At the end of a 4-hour period, there shall be no perceptible drop in the system pressure as observed with a 4-1/2-inch 110 millimeter calibrated instrument gage having a full scale of not more than 16 psig 110 kilopascal. Flange joints and connectors shall be subject to soap-bubble tests as may be directed by the Contracting Officer. Leakage discovered shall be repaired. Pressurization leakage tests shall have been completed prior to the start of electrical acceptance testing.

3.4.3.3 Electrical Testing Cables and Waveguides

Pressure testing shall have been completed and accepted by the Contracting Officer prior to electrical tests.

The following tests shall be performed as acceptance tests:

TEST	COAXIAL CABLE	WAVEGUIDES
Continuity	x	-
Conductor Resistance	x	-
Insulation Resistance	x	-
Attenuation	x	x
Standing Wave Radio (SWR)	x	x
Sweep Frequency	x	x
Operational Fixed Frequency	x	x

Government acceptance of the Contractor's conductor sectional system tests shall not relieve the Contractor of the responsibility of administering the quality assurance and inspection system to ensure completion of work in compliance with contract requirements.

Contractor shall ensure that the test values are within the acceptable limits for each type of test to the satisfaction of the Contracting Officer.

3.4.3.4 Test Equipment

Test equipment required to perform testing shall be furnished by the Contractor.

3.4.4 Testing Outside Plant Communication Cables

Testing outside plant communication cables shall be as follows:

Instrumentation and communication cables shall be tested as provided in applicable specifications.

Cable tests shall be comparable in methods and accuracies to those contained in referenced specifications and shall include the methods and specifications contained herein.

Insulation-resistance tests shall be in accordance with TO 31W3-10-15. In addition, the following minimum requirements shall apply:

Minimum insulation-test values for outside plant cable are shown on Table 3-5 of TO 31W3-10-15.

The output voltage of the insulation resistance test set shall be applied for at least 5 seconds before each reading is taken.

All modules shall be removed on terminations equipped with overvoltage protectors prior to testing.

The minimum insulation resistance shall be 500 megohms per mile.

Wideband cable shall be tested with a high-potentiometer.

Conductor and loop resistance and continuity tests shall be in accordance with TO 31W3-10-15. Cable-length tests shall be performed with a Wheatstone bridge. End-to-end resistance tests shall be performed on each conductor of each cable. Values shall be in accordance with design data sheets. Continuity shall be verified by resistance test.

Defective-pair tests shall be in accordance with TO 31W3-10-15. In addition, every pair in each cable shall be tested for shorts, grounds, crosses, opens, and transpositions. In paper-insulated conductor cables, defective pairs shall be eliminated by transposing the defective pair with the spare pairs at the test-splice location. For plastic-insulated connector cables, defective conductors traceable to conductor connections shall be corrected at the defect. There shall be no defective pairs in plastic-insulated cable.

Attenuation tests shall be performed to find the logarithmic decrement in transmitted power per unit length of each wideband cable pair. The attenuation, expressed in decibels per 100 feet 30 meter, shall be measured at low power so the resulting temperature rise will be negligible. An acceptable method for measuring attenuation is described in MS MIL-C-17/GEN.

Pulse tests (internal echo) shall be performed on each wideband cable pair to determine the mechanical and electrical structure of each splice and connector or installation damage. Pulse shall be a sine-wave squared pulse with a 1- to 4-mHz repetition rate, 0.25 microsecond wide, midpoint between base and peak. Loss shall not exceed minus 36 dB below the incident wave at any one point on the cable. Any greater losses will not be accepted. An acceptable method for performing the pulse test is shown in MS MIL-C-9660.

In addition, the following minimum requirements shall apply to wideband cable testing:

Conductor resistance shall not exceed 23 ohms per mile 1.6 kilometer of cable at 63 degrees F 17 degrees C.

The mutual capacitance shall be not more than 0.058 microfarad per mile 1.6 kilometer.

Capacitance unbalance between conductors and shield shall not exceed 0.50 picofarad per foot 300 millimeter.

Insulation shall be capable of withstanding dc test potential for 2 seconds (maximum instantaneous) of 1,400 volts between conductors and between conductors and shield; for B type termination, 500 volts shield to ground.

Characteristic impedance shall be 125.5 plus or minus 3.5 ohms.

-- End of Section --